ER001581
ENVIRONMENTAL RESTORATION
DIVISION DMC

ORNL/CF-84/202
Internal Use Only

ornl

OAK RIDGE
NATIONAL
LABORATORY

MARTIN MARIETTA

PRELIMINARY RADIOLOGICAL CHARACTERIZATION OF THE OLD HYDROFRACTURE FACILITY (OHF) AT OAK RIDGE NATIONAL LABORATORY

ENVIRONMENTAL RESTORATION DIVISION
DOCUMENT MANAGEMENT CENTER
BLDG 1210 MS 7256

S. F. Huang
R. K. Owenby
W. F. Ohnesorge
K. L. Daniels
M. A. Montford
C. R. Guinn
J. B. Watson
N. A. Teasley
J. S. Eldridge
T. W. Oakes

INTERNAL USE ONLY

CAUTION

This document has not been given final patent clearance and is for internal use only. If this document is to be given public release, it must be cleared through the site Technical Information Office which will ensure that the proper patent and technical information reviews are completed in accordance with Energy Systems Policy. DM for PTO

SEP 20 1991 # 1063

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Publicly Releasable

This document has received the necessary patent and technical information reviews and can be distributed without limitation.

RECORD COPY

ER001581

ENVIRONMENTAL RESTORATIO
DIVISION DMC

ORNL/CF-84/202
Internal Use Only

Environmental and Occupational Safety Division

PRELIMINARY RADIOLOGICAL CHARACTERIZATION OF THE OLD HYDROFRACTURE FACILITY (OHF) AT OAK RIDGE NATIONAL LABORATORY

S. F. Huang
R. K. Owenby
W. F. Ohnesorge
K. L. Daniels
M. A. Montford
C. R. Guinn
J. B. Watson
N. A. Teasley
J. S. Eldridge
T. W. Oakes

Date of Issue — September 1984

Internal Use Only

NOTICE: This document has not been given final patent clearance, and the dissemination of its information is only for official use. If this document is to be given public release, it must be reviewed in accordance with internal release procedures (D-8-5).

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC5-840R21400

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

The authors would like to acknowledge the Environmental and Occupational Safety Division staff for their valuable support. We would also like to thank D. R. Simpson for providing valuable information and the Information Center Complex Publications Office for technical assistance in compiling this report.

ABSTRACT

The Old Hydrofracture Facility (OHF) was operated as a terminal process station of the Oak Ridge National Laboratory Intermediate-Level Waste (IWL) Processing System between 1964 and 1979. The average concentration of radionuclides in the grout mixture prior to injection through OHF was approximately 10 MBq/mL (0.26 mCi/mL) or less for beta-gamma-emitting radionuclides and 370 Bq/g (10 nCi/g) or less for transuranic alpha-emitting radionuclides. More than 8 x 10^6 L of ILW grout mixture containing over 2 x 10^4 TBq (0.6 MCi) of ^{137}Cs and 1 x 10^3 TBq (40 kCi) of ^{90}Sr, along with smaller quantities of other radionuclides, were permanently injected into the impermeable shale formation at depths between 210 and 310 m. This report describes the history, current condition, preliminary radiological characterization, and potential problem areas of this facility.

Surface water and soil samples and subsurface sediment and soil samples were collected and analyzed, and surface radiation levels were mapped. The size of the surveyed area was approximately 66 x 86 m. The interior areas of the OHF are highly contaminated with fixed and transferable activity. The waste tanks, waste pond, and waste pit are potential radiation hazards and contamination sources.

The contamination at the OHF appears to be localized. No apparent leaks were identified in the vicinity of the tanks, pond, and pit.

1. INTRODUCTION

The decontamination and decommissioning (D&D) activities at Oak Ridge National Laboratory (ORNL) are managed under the Surplus Facilities Management Program (SFMP), which is a part of the Department of Energy's (DOE's) SFMP.

In support of the ORNL's SFMP, the Department of Environmental Management (DEM) and the Radiation and Safety Surveys Department of the Environmental and Occupational Safety Division (E&OSD) are responsible for preliminary radiological characterization of retired nuclear facilities, as part of a long-range planning effort. In this report, the status of the Old Hydrofracture Facility (OHF) is described.

The operational history and the geographic features of the OHF have been discussed by others [1,2] and will be discussed only briefly in this report. The monitoring wells associated with the OHF have been extensively studied.[3-5] Because these wells present no relevant impact to the SFMP at ORNL, they are not discussed in this report.

The objectives of the current study are:

1. to identify and characterize the structures that became contaminated during the operation of this facility;
2. to identify surface and subsurface (0–8 m) soil and water contamination in the vicinity of the site;
3. to inventory the radionuclide contents of the pond, the waste pit, and the waste storage tanks; and
4. to inventory the polychlorinated biphenyls (PCBs) and hazardous heavy metal content of the pond.

2. DESCRIPTION OF THE OLD HYDROFRACTURE FACILITY (OHF)

2.1 LOCATION

The OHF is located in Melton Valley in the southwest part of Solid Waste Storage Area No. 5 (SWSA 5), as shown in Figs. 1 and 2. The OHF drainage is to the southwest into White Oak Creek (120 m away), which flows into White Oak Lake and hence into the Clinch River.

2.2 FUNCTION AND HISTORY

The OHF was operated as a terminal process station of the ORNL Intermediate-Level Waste (ILW) Processing System between 1964 and 1979.[1,2] The average concentration of radionuclides in the grout mixture prior to injection through OHF was approximately 10 MBq/mL (0.26 mCi/mL) or less for beta-gamma-emitting radionuclides and 370 Bq/g (10 nCi/g) or less for transuranic alpha-emitting radionuclides.[3,4]

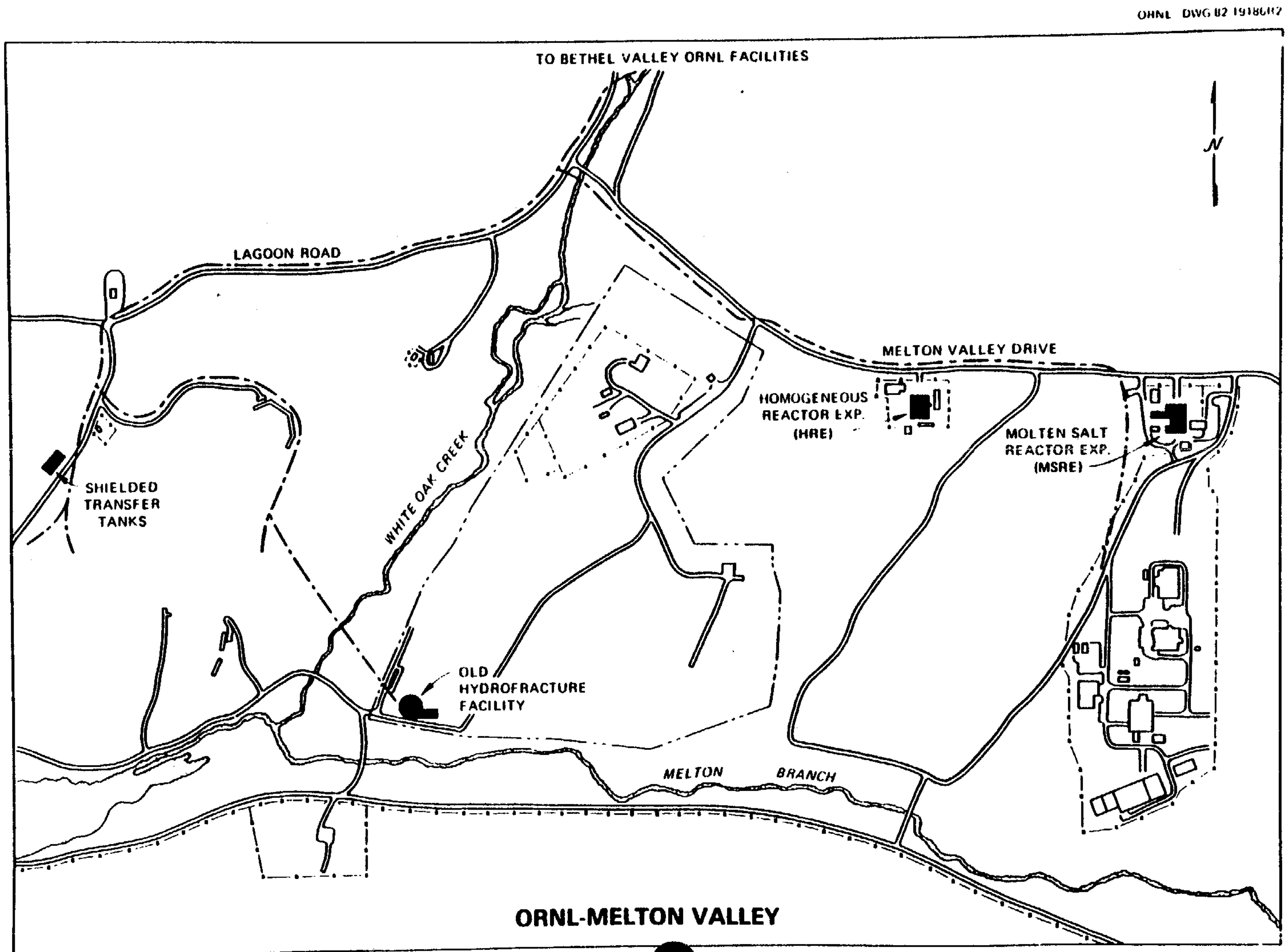


Fig. 1. Area map of the ORNL facilities at Melton Valley (1 in. = 300 m).

ORNL-PHOTO 0033-78

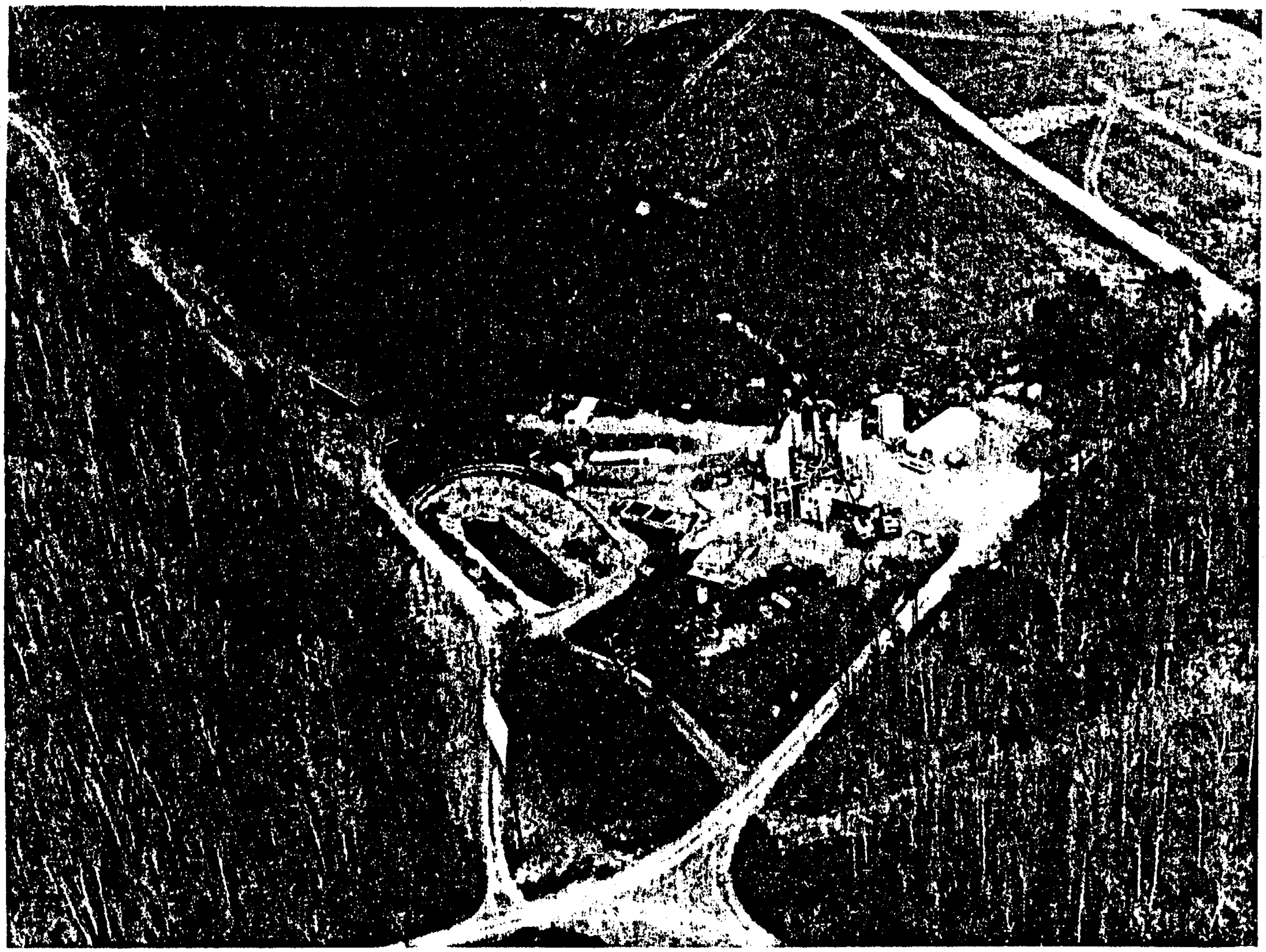


Fig. 2. The Old Hydrofracture Facility.

More than 8 x 10^6 L of ILW grout mixture containing over 2 x 10 TBq (0.6 MCi) of ^{137}Cs and 1 x 10^3 TBq (40 kCi) of ^{90}Sr, along with smaller quantities of other radionuclides, were permanently injected into the impermeable shale formation at depths between 210 m and 310 m. This is well below the deepest known water-bearing formation.[5] The waste process facilities of OHF are likely to be contaminated with a similar proportion of radionuclides. Most of these facilities are marked on Fig. 3 and are identified in the following paragraphs based o their previous functions.[1,2]

2.3 WASTE RETENTION POND

The Waste Retention Pond is approximately 6 x 30 x 1.8 m deep,[6] an the sides are lined with limestone rip-rap. An ORNL drawing (DWG No. 540002-A-002-0) indicated that the pond was to be lined with liquid asphalt (Type RC-1); however the presence of a liner has not been confirmed. The elevation of the bottom of the pond is approximately 233 m (764 ft), and the elevation of the dam is approximately 235 m (771 ft). The pond is located on a gently sloping area that drains to the west. The pond was designed to receive any waste-grout mixtures accidentally released between 1964 and 1979. In the course of a waste injection the potential existed for wellhead rupture. Such a rupture would allow the injection grout to flow back up the well with no way of stopping the flow. In such an event, the waste grout mixture was to flow from the wellhead cell through an underground waste line [46 cm (18 in.) diam] t the 3.2 x 10^5-L waste pond. No accidental ruptures occurred durin he operational life of the facility that required this emergency basin. Contamination in the pond resulted from wastewater rinsing of equipment

2.4 WASTE PIT

The waste pit is located off the southeast corner and at a slightl higher elevation than the pond. Radionuclides in the pit and in the injected ILW grout mixture are expected to be the same.

The waste pit consists of three concrete compartments, 3.7 x 3.7 x 2.7 m deep.[3] Currently, one of the compartments is sealed, and the othe two are filled with contaminated water and sand mixed with organic materials but are covered with a fiberglass panel structure. The waste pit was used to temporarily store contaminated water and degraded sand generated from slotting the casing of the injection well as well as frc washing of equipment after injection.

2.5 WASTE TANKS

Five carbon steel storage tanks, T-1, T-2, T-3, T-4, and T-9, are buried approximately 1.2 m below-grade in a gently sloping area that drains toward the southwest. The tanks were used to store ILW solutio prior to its permanent disposal. The tanks are under cathodic protection and are ventilated through a HEPA filter to the atmosphere. They were placed horizontally in the area southwest of the pump room sh i Fig. 3. These tanks are believed to be structurally sound. A 30-

ORNL-DWG 84-12845

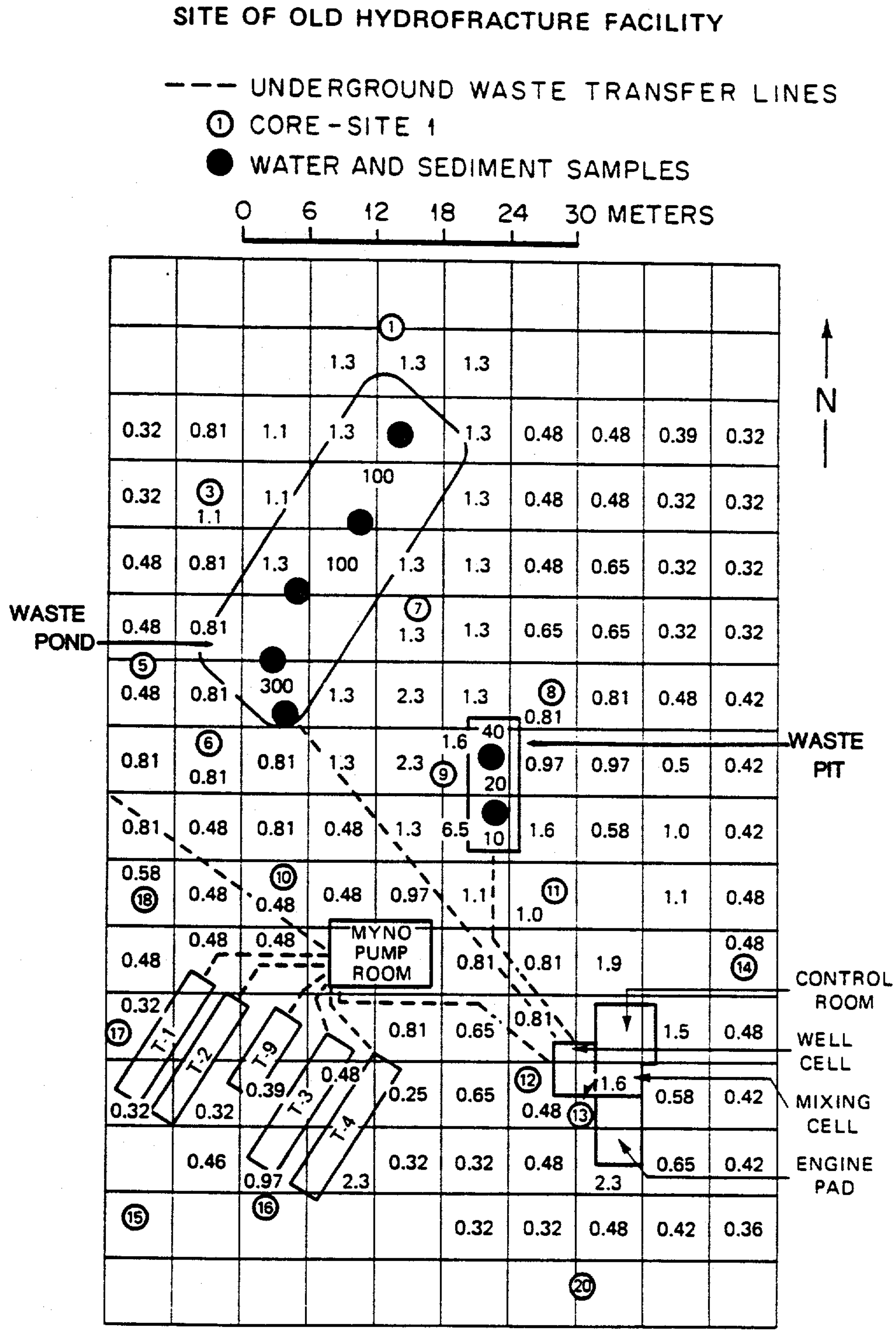


Fig. 3. Beta-gamma direct readings exceeding 0.3 mrad/h (1 mrad = 10 μGy) at 1 to 3 cm above the surface.

layer of residual ILW is expected in each tank (an estimate based o operating experience).

2.6 CONTROL ROOM

The control room is a concrete structure adjacent to the mixing cell. It contains a control panel board and a few stored items.

2.7 MIXING, PUMP, AND WELL CELLS

Three cells were used for the mixing, pumping, and injection activities and are continuously ventilated through a filter. All cells were built with a 30-cm thick concrete wall and have a roof covered with sheet metal. The cells were painted but unlined. The size of the mixing, pump, and well cells is 3.9 x 3.5 x 2.4 m, 3 x 2.2 x 2.4 m, and 3.4 x 3.4 x 3 m, respectively. Located south of these cells is a 3 x 6 m engine pad.

2.8 PUMP ROOM

The pump room, a partially underground concrete structure (5 x 8 x 2.4 m), houses two modified Moyno pumps. Currently, the pump room is under minimum maintenance and is continuously ventilated through a filter.

2.9 VALVE PIT

Most of the valves in the waste handling system are mounted in a valve pit adjacent to the pump room. The valve pit is 0.9 x 2.6 x 1.5 m deep and is made of concrete block covered with sheet metal.

2.10 PIPE SYSTEM

Underground lines served to connect the tanks, the valve pit, and the pump room with the cells, the waste pit, and the pond. These lines are likely to be still in place and their interior is potentially contaminated. Some of these pipe lines are marked on Fig. 3.

3. EXPERIMENTAL PROCEDURES

Most of the methods and techniques used in this study are the same as those previously used.[7] Surface and subsurface samples were collected using hand coring and deep soil coring techniques; surface areas were divided into grids, and walk-over surveys were performed. A grid size of 6.1 m was used for the outdoor areas. The interior areas of onsite structures were not gridded.

Pond samples were collected from five sampling sites, marked on Fig. 3. A plastic tube, 7.6 cm diam and 1.5 m long, was used at each site. This tube was hammered into the clay bottom until refusal. The tube was removed from the pond after sealing the top with a rubber stopper. The water column and sediment were removed together. Th water in the tube was drained by punching a hole in the side of the sampling tube. The core was pushed out of the end of the tube. The clay and sediment portions were separated, homogenized, and analyzed. Separate portions were taken for radionuclide and hazardous material analysis. From each cell of the waste pit, a sediment sample and a water sample were collected using a small scoop with a long handle. In an attempt to achieve a more representative sample, the sediment samples were taken by dragging the scoop over a wide area in each cell. Only one sample was taken, and only one depth measurement was made in each cell.

Standard ORNL radiation survey instruments were used for all surveys. Beta-gamma readings were made with a GM meter, a Victoreen 440 (a low-range air ionization chamber), or a Cutie Pie.[8] Smear samples were taken over areas of approximately 100 cm^2 and counted in alpha and beta-gamma sample counters or with a portable survey instrument (for samples with high levels of contamination).

Seventeen deep soil cores were taken near potential radiation hazards. All sites were identified by a number, and their actual locations were specified by ORNL coordinates. As a reference, the ORNL coordinates of these core sites and the corresponding drilling depths are provided in Table 1. Sample sequence numbers and their corresponding depths are:

Sequence number	Depth (m)
1	0–0.3
2	0.3–0.6
3	0.6–1.2
4	1.2–1.8
5	1.8–2.4
6	2.4–3.1
7	3.1–3.7
8	3.7–4.3
9	4.3–4.9
10	4.9–5.5

Each sample collected using deep soil coring techniques was identified by two numbers separated by a dash (–). The first number specified the core site, and the second number was a sequence number that specified the relative depth at which that sample was collected. For example, sample 6–3 was collected at core site six, at a depth of 0.6 to 1.2 m.

Most soil and groundwater samples were counted on a 15 x 15 cm NaI(Tl) detector for 5 min. The total integral counts and a gamma-ray spectrum between the energy range 100 and 1500 keV were obtained.[7,9] Based on these results, a smaller number of samples were selected,

Table 1. ORNL coordinates for deep soil core sites and the corresponding drilling depths at the OHF site

Core site	ORNL coordinates[a] N	ORNL coordinates[a] E	Maximum drilling depth (m)
1	17,381	28,570	3.1
3	17,300	28,510	3.7
5	17,265	28,485	3.7
6	17,245	28,510	3.7
7	17,285	28,580	3.7
8	17,265	28,600	5.5
9	17,240	28,570	4.9
10	17,210	28,533	5.5
11	17,205	28,610	7.3
12	17,155	28,600	4.3
13	17,143	28,615	6.7
14	17,180	28,665	5.5
15	17,135	28,480	5.5
16	17,115	28,535	5.5
17	17,165	28,470	2.4
18	17,210	28,290	4.9
20	17,066	28,619	4.9

[a]Measured in feet.

processed, and analyzed for gamma emitters by high resolution gamma-ray spectroscopy and for ^{90}Sr and $^{238,239}Pu$, ^{241}Am, ^{244}Cm, and uranium by radiochemical techniques.[7,10] Due to the high dose rates of samples from the pond and the waste pit, these samples were not counted on the NaI detector. Analytical results are reported in units of becquerels per gram of dried sample or per milliliter of filtered liquid, unless otherwise specified.

4. CRITERIA

In the current study, the guidelines to be used in identifying potential problem areas are summarized in Tables 2 and 3. The ORNL Health Physics (HP) guide for establishing radiation zones is summarized in Table 2.[11] The ORNL HP guide for designating a radiation source or hazard or a contamination zone is shown in Table 3. Table 4 shows background radioactivity in soil samples from perimeter areas around the DOE Oak Ridge Reservation and from remote areas 19 to 121 km from ORNL.[12] The levels shown in Table 4 are typical of the East Tennessee area and are primarily due to natural radioelements and global fallout.

Table 5 includes the radionuclide concentrations in the Clinch River measured in 1981 at Melton Hill Dam.[12] These are used as background concentrations.

5. CALCULATIONS

The inventory of radionuclides in sediment or clay in the pond is obtained using the following equation:

$$\text{Inventory (Bq)} = C \times W ,$$

where C = average concentration of radionuclide (Bq/g wet wt).
W = total weight, moist sediment or clay (8×10^4 kg for sediment, 4×10^4 kg for soft clay).

6. RESULTS

6.1 OUTDOOR RESULTS

General radiological mapping of the interior and exterior areas of the OHF was accomplished with portable survey instruments [GM Meter, Victoreen 440, Cutie Pie, and Long Tom (a high-range Cutie Pie with an extended probe)]. Elevated absorbed dose rates were measured over the entire survey area. Survey results for the outdoor areas are marked on Fig. 3, in units of mrad/h. To determine the surface and subsurface soil contamination in the vicinity of OHF, 144 soil samples from 17 core sites, marked on Fig. 3, were collected and analyzed. The results of the preliminary gamma screening and the quantitative ^{137}Cs analysis are listed in Table 6. Other radionuclides identified were ^{60}Co, ^{90}Sr, uranium, and transuranic elements. Two samples are of particular

Table 2. ORNL guide[a] for establishing radiation zones

Category	Dose rate range (mSv/h)	Dose rate range (mrem/h)	Actions required
1	0.03–0.06	3–6	Post low-level tags; define zone boundaries and establish access control if the daily dose may be 20 mrem
2	0.06–10	6–1000	Post warning signs or tags, define zone boundaries, and establish positive access control
3	10–50	1000–5000	Post warning signs or tags and erect a barricade that provides for absolute control of personnel access to the area
4	>50	>5000	Post warning signs or tags (Bull's Eye Radiation Hazard Sign if ≥10 rem/h) and erect a barricade that provides for absolute exclusion of unauthorized personnel with entrances locked or blocked

[a]Adapted from the <u>ORNL Health Physics Procedures Manual</u>, Sect. 2.7 (Ref. 11).

Table 3. ORNL health physics guide[a] for designating a radiation source or hazard

Type of measurement	Condition
1 External dose equivalent rate (unshielded)	>2.5 μSv/h (>0.25 mrem/h)
2 Surface alpha direct reading	>300 dpm/100 cm^2
3 Surface alpha smear reading	>20 dpm/100 cm^2
4 Surface beta-gamma direct reading	>2.5 μGy/h (>0.25 mrad/h)
5 Surface beta-gamma smear reading	>200 dpm/100 cm^2

[a]Adapted from the <u>ORNL Health Physics Manual</u>, Sect. 2.3 (Ref. 11).

Table 4. Surface radionuclide concentrations in soil

	Background[a]			
	Remote		Perimeter	
Radionuclides	(mBq/g)	(pCi/g)	(mBq/g)	(pCi/g)
^{137}Cs	52	1.4	49	1.3
^{90}Sr	7	0.2	14	0.4
^{238}Pu	0.2	0.005	0.1	0.003
^{239}Pu	2.7	0.08	1.5	0.04
^{235}U	1.1	0.03	1.1	0.03
^{238}U	19	0.5	15	0.4
^{232}Th	NA		33	0.9

[a]Adapted from the Industrial Safety and Applied Health Physics Division Annual Report for 1981 (Ref. 12). "Perimeter" indicates data accumulated from the area within a 16-km radius of the ORNL areas, and "Remote" indicates data accumulated from the area outside of the perimeter area but within 80 km of the ORNL.

Table 5. Radionuclides measured in water at Melton Hill Dam and the mouth of White Oak Creek[a]

	Melton Hill Dam		Mouth of White Oak Creek	
Radionuclides	(mBq/L)	(pCi/L)	(Bq/L)	(pCi/L)
^{90}Sr	48	1.3	2.3	62
^{137}Cs	3	0.08	0.37	10
^{60}Co	8	0.2	1.2	33

[a]Data were accumulated in 1981 (Ref. 12).

Table 6. Preliminary gamma screening results and quantitative gamma and beta analyses on soil samples

Sample	Gamma Activity (cps/kg)[a]	^{137}Cs (Bq/g)[b]	Sample	Gamma Activity (cps/kg)	^{137}Cs (Bq/g)
1-1	<80	NA[c]	8-10	35	ND
1-2	33	NA	9-1[d]	<30	0.05
1-3	44	NA	9-2	28	NA
1-4	44	NA	9-3	60	0.56
1-5	34	NA	9-4	31	NA
1-6	42	NA	9-5	37	NA
3-1	66	0.37	9-6	35	NA
3-2	29	0.04	9-7	37	NA
3-3[d]	55	0.12	9-8	35	NA
3-4[d]	420	2.9	9-9	28	NA
3-5	65	0.2	10-1[d]	470	3.5
3-6	45	NA	10-2	120	1.0
3-7	32	NA	10-3	240	NA
3-8	34	NA	10-4[d]	34	0.03
5-1	35	0.09	10-5	38	NA
5-2	41	NA	10-6	25	NA
5-3	30	NA	10-7	32	NA
5-4	28	NA	10-8	38	NA
5-5	32	NA	10-9[d]	66	NA
5-6	33	NA	10-10	46	NA
5-7	31	NA	11-3	35	NA
6-1	41	0.2	11-4	36	NA
6-2	32	NA	11-5	38	NA
6-3	34	NA	11-6	38	NA
6-4	37	NA	11-7	34	NA
6-5	29	NA	11-8	30	NA
6-6	45	NA	11-9	30	NA
6-7	46	NA	11-10	29	NA
7-1[d]	96	1.1	11-11	32	NA
7-2	38	NA	11-12	32	NA
7-3	38	NA	11-13[d]	38	ND
7-4	31	NA	12-3	36	NA
7-5	32	NA	12-4	39	NA
7-6	34	NA	12-5	34	NA
7-7	34	NA	12-6	34	NA
8-3	44	NA	12-7	81	ND
8-4	24	NA	12-8[d]	240	ND
8-5	34	NA	13-3[d]	130	0.74
8-6	28	NA	13-4	68	0.35
8-7	53	NA	13-5[d]	70	0.26
8-8	26	NA	13-6	46	0.07
8-9	37	NA	13-7	69	0.52

Table 6 (continued)

Sample	Gamma Activity (cps/kg)[a]	^{137}Cs (Bq/g)[b]	Sample	Gamma Activity (cps/kg)	^{137}Cs (Bq/g)
13-8[d]	260	3.2	16-6	54	NA
13-9	40	0.02	16-8	33	NA
13-10	50	0.32	16-9	32	NA
13-11	58	0.27	16-10	67	NA
13-12	37	0.02	17-1	29	0.01
14-3	81	0.67	17-2	29	NA
14-4	84	0.31	17-3	30	NA
14-5	43	NA	17-4	32	NA
14-6	45	NA	17-5	40	NA
14-7	37	NA	18-1	43	0.17
14-8	41	NA	18-2	32	NA
14-9	34	NA	18-3	41	NA
14-10	53	<0.01	18-4	33	NA
15-1[d]	51	0.19	18-5	30	NA
15-2	43	NA	18-6	34	NA
15-3	40	NA	18-7	31	NA
15-4	33	NA	18-8	31	NA
15-5	40	NA	18-9	34	ND
15-6	31	NA	20-1	<30	0.05
15-7	64	NA	20-2	20	NA
15-8	41	NA	20-3	27	NA
15-9	42	NA	20-4	36	NA
15-10[d]	35	ND	20-5	31	NA
16-1[d]	88	0.48	20-6	31	NA
16-2	43	NA	20-7	37	NA
16-3	36	NA	20-8	39	NA
16-4	42	NA	20-9[d]	41	NA
16-5[d]	53	0.33			

[a]cps/kg indicates counts per second per kilogram of moist soil. Natural background is approximately 20-40 cps/kg on the detector used for this study (15 x 15 cm NaI (TI) detector; energy span 100-1500 keV).

[b]1 Bq = 27 pCi.

[c]NA indicates not analyzed and ND indicates not detectable.

[d]Sample also analyzed for ^{90}Sr, uranium, and transuranic elements.

interest due to their measured radionuclide concentrations. In sample 3-4, concentrations for specific radionuclides are 2.9 Bq/g (78 pCi/g) for ^{137}Cs, 0.59 Bq/g (16 pCi/g) for ^{60}Co, 5.7 Bq/g (154 pCi/g) for ^{90}Sr, and trace quantities for transuranic alpha-emitting nuclides. In sample 10-1, concentrations for specific radionuclides are 3.5 Bq/g (95 pCi/g) for ^{137}Cs, 0.48 Bq/g (13 pCi/g) for ^{90}Sr, and trace quantities for alpha-emitting radionuclides. The analytical results of the pond samples (water, sediment, and clay) are given in Tables 7 and 8. Table 9 lists the analytical results and total inventories of radioactivity in the waste pit.

Assuming that the residual sludge in each of the buried waste tanks is 30 cm thick (a rough estimate obtained from operational experience)[13] and the average radioactivity in the sludge is 0.26 mCi/mL, the same as in the grout mixtures,[3] the total inventory in each tank can be estimated.[14] The tank dimension and the estimated residual activity in each tank are shown in Table 10. A summary of the radiological inventories in the outdoor areas is given in Table 11.

6.2 INDOOR RESULTS

Varying radiation and contamination levels in the interiors of the control room, mixing cell, pump cell, well cell, and pump room were found. Because of the high levels of transferable contamination and the rough surfaces, wet paper towel smears were used to detect removable contamination. These smears were then surveyed with portable instrumentation rather than smear counters to prevent contamination of the smear counters. The results of the radiation survey of the interior areas are shown in Figs. 4-9. A summary of these survey results is given in Table 12.

7. DISCUSSION

7.1 IDENTIFICATION OF POTENTIAL RADIATION HAZARDS

7.1.1 Waste Retention Pond

In the study performed on September 7, 1983, the absorbed dose rates 10 cm above the water surface in the pond were between 1 and 3 mGy/h (100 and 300 mrad/h). The pond had approximately a 40-cm water layer and a 20-cm sediment layer, underlain by a soft clay layer. Pond samples were taken from five sites. The approximate locations of these sample sites are marked on Fig. 3. Radionuclide analyses of the pond samples show that the water, sediment, and the underlying clay layer in the pond are all contaminated (see Table 7).

The total activities in the water, sediment, and upper 10 cm of the soft clay are approximately 1.1 GBq, 15 TBq, and 300 GBq (30 mCi, 400 Ci, and 8 Ci), respectively. The major radionuclides are ^{137}Cs, ^{90}Sr, ^{60}Co, and ^{134}Cs. Significant quantities of transuranic alpha-emitting radionuclides also exist in the sediment and underlying clay. The a-

Table 7. Inventories of radionuclides in the OHF pond[a]

Pond content	Average thickness, estimated volume	Radionuclide	Concentration (Bq/g or Bq/mL)[b]		Total activity[c]	
			Average	Highest	(GBq)	(mCi)
Water	0.4 m	^{137}Cs	29	30	2.1	57
	7.4×10^4 L	^{90}Sr	7.1	7.1	0.53	14
		^{60}Co	2.7×10^{-2}	3.0×10^{-2}	2.0×10^{-3}	5.5×10^{-2}
		^{134}Cs	2.7×10^{-2}	3.0×10^{-2}	2.0×10^{-3}	5.5×10^{-2}
Sediment	0.2 m	^{137}Cs	1.8×10^5	4.5×10^5	1.4×10^4	3.8×10^5
	3.7×10^4 L	^{90}Sr	9.7×10^3	3×10^4	770	2.1×10^4
		^{60}Co	740	2.1×10^3	60	1.6×10^3
		^{154}Eu	390[d]	390	31	830
		^{134}Cs	100	220	8.1	220
		^{239}Pu	5.3	15	0.43	12
		^{238}Pu	12	35	0.94	25
		^{241}Am	2.8	7.0	0.22	6.0
		^{244}Cm	160	530	13	360
		^{235}U	2.0×10^{-3}	6.0×10^{-3}	5.0×10^{-6}	2.0×10^{-4}
		^{238}U	0.23	0.62	5.5×10^{-3}	0.15
Soft-clay	0.1 m	^{137}Cs	9.2×10^3	3.3×10^4	370	9.9×10^3
	1.9×10^4 L	^{90}Sr	1.7×10^3	3.5×10^3	67	1.8×10^3
		^{60}Co	14	28	0.56	15
		^{134}Cs	15[d]	15	0.58	16
		^{239}Pu	1.7	2.7	6.6×10^{-2}	1.8
		^{238}Pu	0.9	2.5	3.6×10^{-2}	0.97
		^{241}Am	0.75	2.6	3.0×10^{-2}	0.81
		^{244}Cm	3.3	12	0.13	3.6

[a]Based on samples collected from five locations.

[b]1 Bq = 27 pCi; sediment and clay results are based on wet weight.

[c]Total weights of moist sediment and soft clay are approximately 8×10^4 kg and 4×10^4 kg, respectively.

[d]Based on one sample.

Table 8. Inventory and concentration of polychlorobiphenols (PCBs) and hazardous trace metals in OHF pond sediment

	Concentration[a]		
	Average (μg/g)	Highest (μg/g)	Inventory[b] (g)
PCB	3.5	15	280
Hg	<2.3	<3	<180
Sb	<0.96	2.1	<77
Pb	6	12	480
Cd	<2.0	<2.4	<160
Se	<0.78	<1.2	<62
As	1.1	1.8	86
Cr	17	27	1300
Zn	16	21	1200
Cu	18	30	1400

[a]Reported on wet weight basis.

[b]Total weight of the moist sediment was estimated to be approximately 8×10^4 kg.

Table 9. Waste pit inventories of radionuclides

	Average depth and volume	Radio-nuclide	Concentration (Bq/mL or Bq/g)[a]	Inventory[b] (GBq)	(mCi)
South Cell Water	45 cm	^{137}Cs	1.2×10^2	0.8	20
	6.3×10^3 L	^{239}Pu	1.1	0.007	0.2
		^{238}Pu	2.2	0.01	0.4
		^{241}Am	<1	0.006	0.2
		^{244}Cm	1.0	0.006	0.2
		^{90}Sr	15	0.09	3
South Cell Sediment	10 cm	^{137}Cs	4×10^3	6	200
	1.4×10^3 L	^{60}Co	31	0.04	1
		^{239}Pu	97	0.1	4
		^{238}Pu	30	0.04	1
		^{241}Am	17	0.02	0.6
		^{244}Cm	54	0.08	2
		^{90}Sr	7.8×10^2	1	30
North Cell Water	90 cm	^{137}Cs	2.1×10^2	3	80
	1.3×10^4 L	^{239}Pu	1	0.01	0.4
		^{238}Pu	1.5	0.02	0.5
		^{241}Am	<1	<0.01	<0.4
		^{244}Cm	<1	<0.01	<0.4
		^{90}Sr	16	0.2	6
North Cell Sediment	10 cm	^{137}Cs	3.1×10^3	4	100
	1.4×10^3 L	^{60}Co	14	0.02	0.6
		^{239}Pu	42	0.06	2
		^{238}Pu	17	0.02	0.6
		^{241}Am	13	0.02	0.6
		^{244}Cm	6×10^2	0.8	20
		^{90}Sr	4×10^2	0.6	20

[a]1 Bq = 27 pCi.

[b]Inventory in the sediment was estimated by assuming that the total volume was equal to the total dry weight.

Table 10. Estimate[a] of residual radioactivity in waste tanks at the OHF

Tank[b]	Tank capacity (L)	Tank diameter (m)	Tank length (m)	Sludge volume (L)	Sludge activities (TBq)	(kCi)
T-1	5.9×10^4	2.4	13	4.2×10^3	40	1
T-2	5.9×10^4	2.4	13	4.2×10^3	40	1
T-9	4.4×10^4	3.1	5.9	2.2×10^3	30	0.6
T-3	1.1×10^5	3.2	13	4.9×10^3	40	1
T-4	1.1×10^5	3.2	13	4.9×10^3	40	1

[a]The estimate was based on the assumption of 30 cm thickness of residual sludge (a rough estimate from operational experience) at a concentration of 0.26 Ci/L (Ref. 5,13).

[b]Tanks are positioned horizontally.

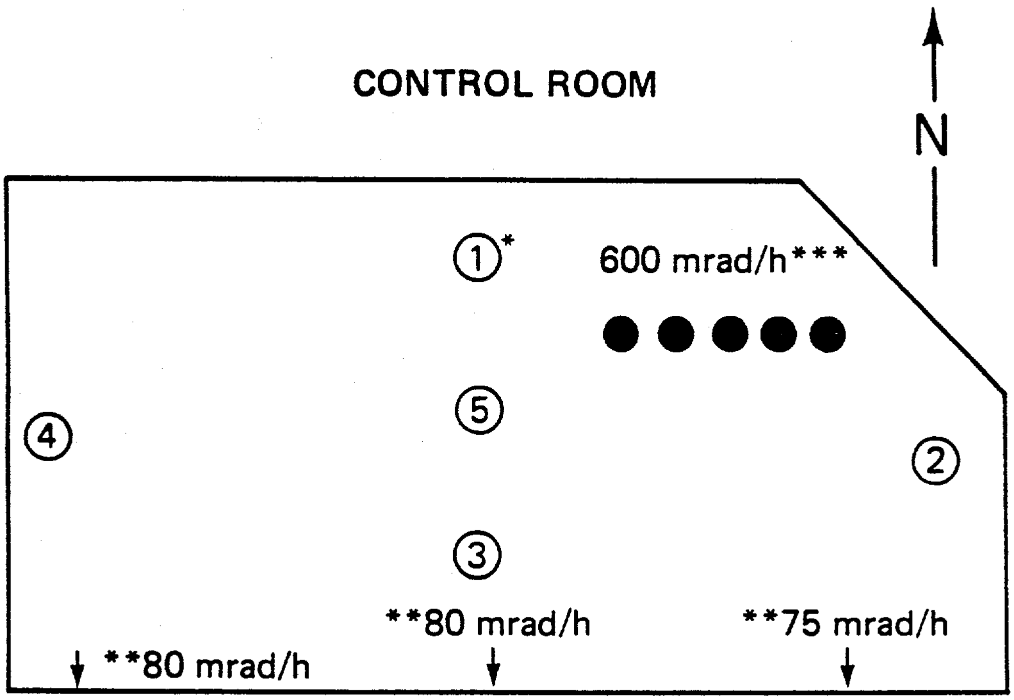
Table 11. Summary of the radiological inventories in the waste tanks, pond and pit of the OHF

	Material type	Inventory (TBq)	(Ci)[a]	Volume (L)
Waste tanks	Sludge	200	5,000	2×10^4
Waste pond	Water	0.003	0.07	7×10^{4a}
	sediment/clay	15	400	6×10^4
Waste pit[b]	Water	0.004	0.1	2×10^4
	sediment	0.01	0.3	3×10^3

[a]Water volume in the pond varies with weather. The volume used in this report was measured in the summer while the water level was low.

[b]Total radioactivity at the waste pit could be significantly more due to the presence of solidified materials that could not be sampled with available equipment.

ORNL—DWG 84-12881



*SMEAR SAMPLE LOCATION
**READING AGAINST THE WALL
***READING FROM FIVE STORED ITEMS

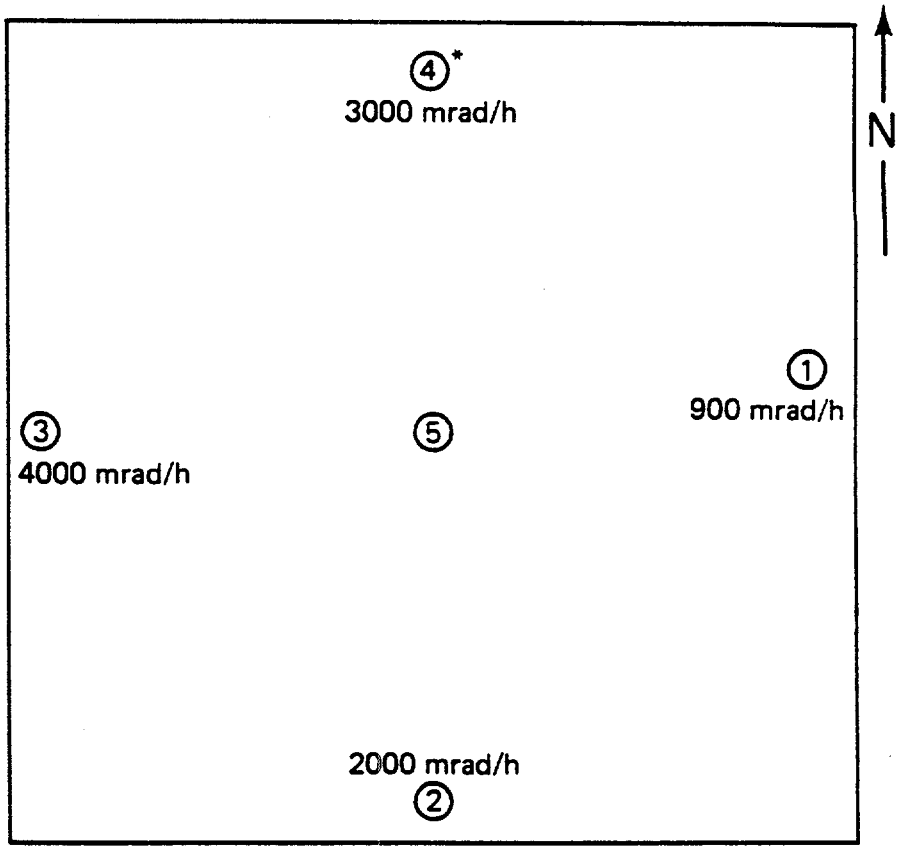
SMEARABLE ACTIVITY PER 100 cm^2

LOCATION	BETA-GAMMA	ALPHA
1	49,000 dpm	<20 dpm
2	32,000 dpm	<20 dpm
3	63,000 dpm	30 dpm
4	28,000 dpm	20 dpm
5	21,000 dpm	40 dpm

Fig. 4. Radiological survey results of the control room (1 mrad = 10 µGy). Direct beta-gamma readings are marked.

ORNL–DWG 84-12880

MIXING CELL



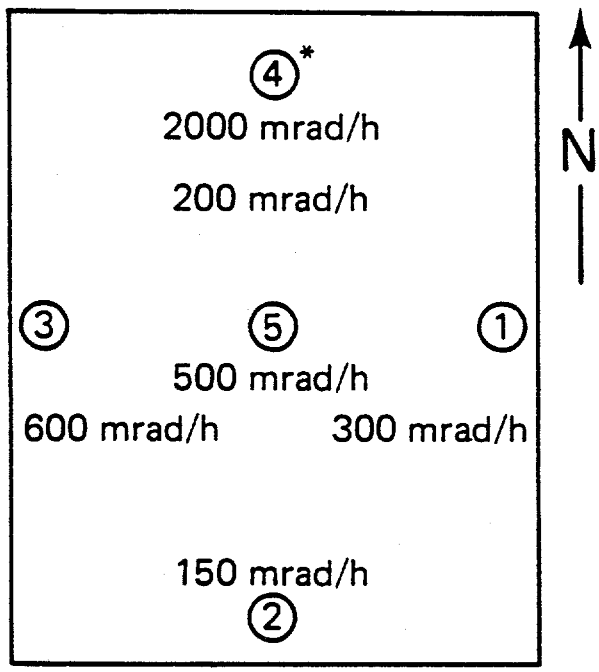
*SMEAR SAMPLE LOCATION

	SMEARABLE ACTIVITY PER 100 cm^2	
LOCATION	BETA-GAMMA	ALPHA
1	15 mrad/h	100 dpm
2	15 mrad/h	<20 dpm
3	15 mrad/h	<20 dpm
4	5 mrad/h	<20 dpm
5	30 mrad/h	<20 dpm

Fig. 5. Radiological survey results of the mixing cell (1 mrad = 10 μGy). Direct beta–gamma readings are marked.

ORNL—DWG 84-12879

PUMP CELL



*SMEAR SAMPLE LOCATION

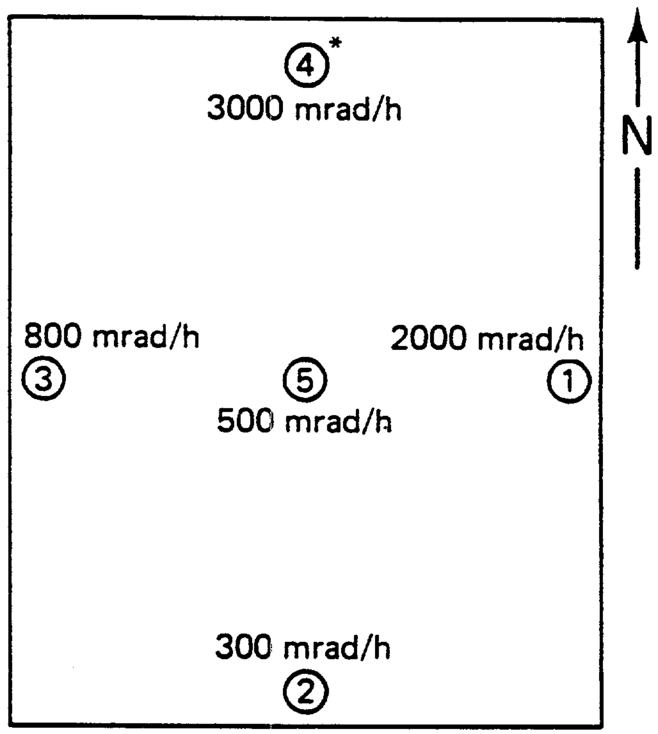
SMEARABLE ACTIVITY PER 100 cm^2

LOCATION	BETA-GAMMA	ALPHA
1	2 mrad/h	< 20 dpm
2	4 mrad/h	< 20 dpm
3	3 mrad/h	< 20 dpm
4	3 mrad/h	< 20 dpm
5	5 mrad/h	< 20 dpm

Fig. 6. Radiological survey results of the pump cell (1 mrad = 10 μGy). Direct beta-gamma readings are marked.

ORNL–DWG 84-12878

WELL CELL

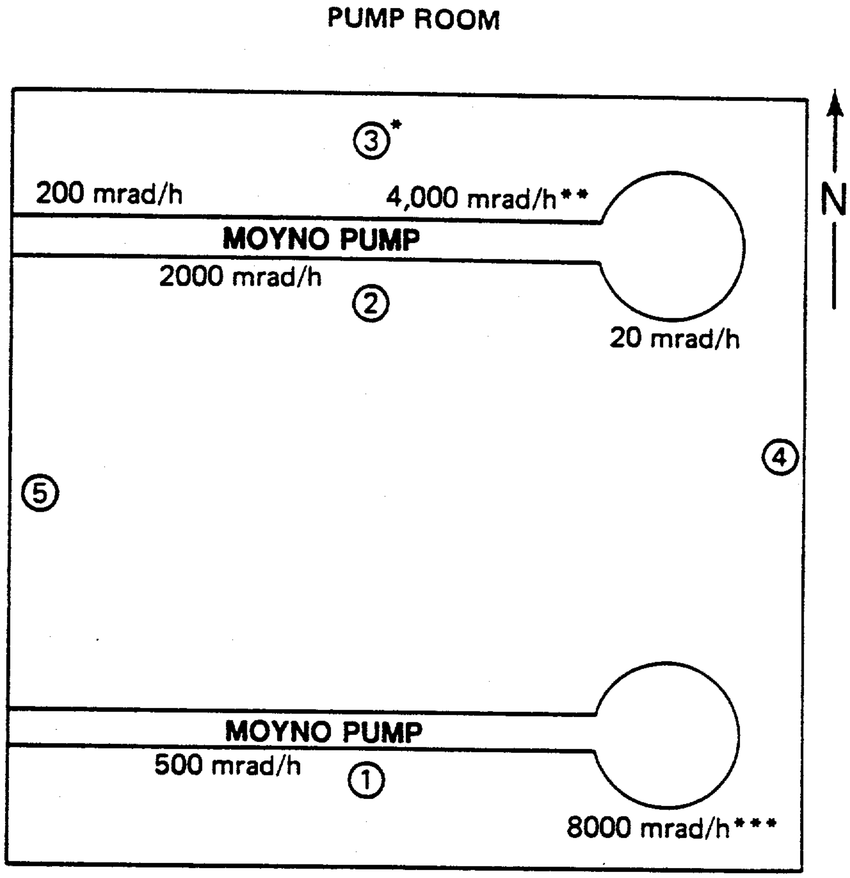


*SMEAR SAMPLE LOCATION

SMEARABLE ACTIVITY PER 100 cm^2		
LOCATION	BETA-GAMMA	ALPHA
1	35 mrad/h	< 20 dpm
2	35 mrad/h	< 20 dpm
3	15 mrad/h	< 20 dpm
4	20 mrad/h	< 20 dpm
5	10 mrad/h	< 20 dpm

Fig. 7. Radiological survey results of the well cell (1 mrad = 10 μGy). Direct beta-gamma readings are marked.

ORNL-DWG 84-12877

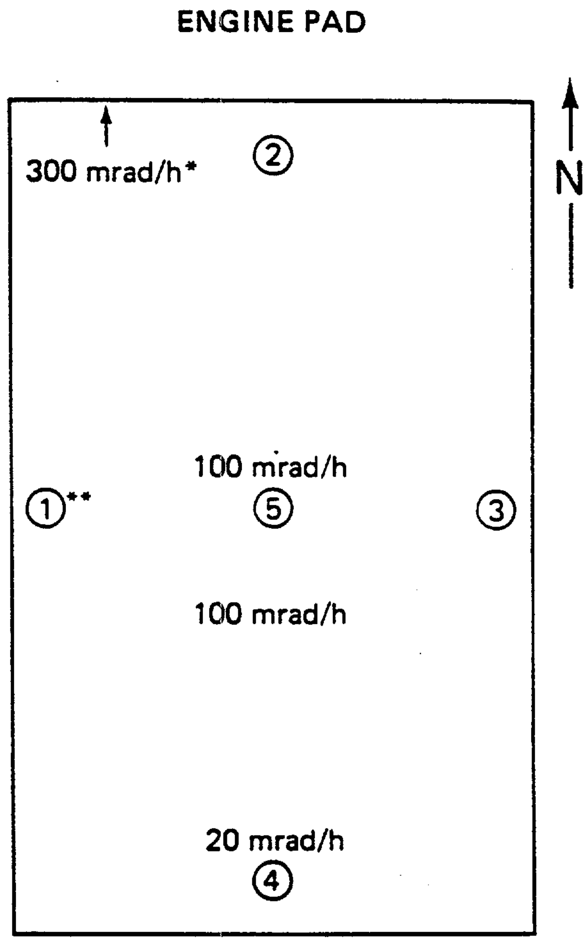


*SMEAR SAMPLE LOCATION
**READING AGAINST THE PUMP
***READING FROM UNDERNEATH A LEAD SHIELD

	SMEARABLE ACTIVITY PER 100 cm^2	
LOCATION	BETA-GAMMA	ALPHA
1	0.5 mrad/h	< 20 dpm
2	15.0 mrad/h	< 20 dpm
3	10.0 mrad/h	< 20 dpm
4	10.0 mrad/h	< 20 dpm
5	8.0 mrad/h	< 20 dpm

Fig. 8. Radiological survey results of the pump room (1 mrad = 10 μGy). Direct beta-gamma readings are marked.

ORNL—DWG 84-12876



*READING AGAINST THE WALL
**SMEAR SAMPLE LOCATION

	SMEARABLE ACTIVITY PER 100 cm^2	
LOCATION	BETA-GAMMA	ALPHA
1	0.75 mrad/h	< 20 dpm
2	0.5 mrad/h	< 20 dpm
3	1.0 mrad/h	27 dpm
4	1.0 mrad/h	< 20 dpm
5	1.0 mrad/h	< 20 dpm

Fig. 9. Radiological survey results of the engine pad (1 mrad = 10 μGy). Smear sample locations and direct beta-gamma dose rates are marked.

Table 12. Summary of the interior survey results at the OHF

Location	Direct radiation levels (mrad/h)	Smearable activity[a] per 100 cm^2		
		Beta-gamma		Alpha
		μGy/h[b]	mrad/h[b]	dpm
Control room	75–600	21,000–49,000 dpm		21-36
Mixing cell	400–4000	50–300	5–30	<20–100
Pump cell	150–2000	20–50	2–5	<20[c]
Well cell	200–3000	100–350	10–35	<20
Pump room	20–8000	5–150	0.5–15	<20
Engine pad	20–300	5–10	0.5–1	<20–27

[a]Wet paper towel techniques were used because of the high levels of transferable contamination and the rough surfaces.

[b]These smears were surveyed with portable instrumentation rather than smear counters to prevent contamination of the smear counters.

[c]Alpha smearable activity ≥20 dpm is the current ORNL guide for defining a contamination zone or contaminated equipment.

age concentrations of uranium in the sediment are 0.23 Bq/g of ^{238}U [illegible] 2.0 mBq/g of ^{235}U.

Table 7, column 8, lists the inventories of all radionuclides. The average and highest concentrations of individual radionuclides are provided in Table 7, columns 4 and 5.

In the summer, the pond contains large quantities of filamentous algae. The algae in the pond is contaminated at levels on the order of 60 kBq of ^{137}Cs per gram of dry algae (2 μCi/g).

Because of the high levels of fission and activation products as well as transuranic alpha-emitting radionuclides, careful planning should be given to determine how to excavate and dispose of the contaminated material in the pond.

Hazardous heavy metals and PCBs were also found in the pond sediment. Table 8, columns 2, 3, 4, and 6, lists the major hazardous chemicals, their average and highest concentrations detected, and their inventories in the sediment. Because the sediment is also contaminated with PCB, special considerations are needed for its disposal.[15]

7.1.2 Waste Pit

In the study performed on January 31, 1984, the absorbed dose rates under the roof of the waste pit were between 0.1 and 0.4 mGy (10 and [illegible]0 mrad/h) (shown in Fig. 3). The south compartment had a water layer [illegible] 45 cm and a sediment layer of 10 cm. The north compartment had a water layer of 90 cm and a sediment layer of 10 cm. The total estimated radioactivity in water and loose sediment is 5 GBq (0.1 Ci) and 10 GBq (0.3 Ci), respectively. Table 9, columns 3, 4, and 5, lists the major radionuclides, concentrations, and total inventories. In addition to the material sampled, solidified materials that could not be sampled with available equipment were present. The total radioactivity in the solidified material could be significantly more than that estimated in water and loose sediment.

7.1.3 Waste Tanks

The residual activity in each tank is estimated to be between 22 and 37 TBq (600–1000 Ci). The total activity for all tanks is roughly estimated to be 170 TBq (4.6 kCi) for 2 x 10^4 L of sludge.

7.1.4 Control Room

An absorbed dose rate of 6 mGy/h (600 mrad/h) was detected from items stored in the control room. In the control room itself, the absorbed dose rates were 0.75 to 6 mGy/h (75–600 mrad/h), and the smearable activity per 100 cm^2 areas was 330–820 Bq (20,000–49,000 dpm) of beta-gamma and 0.3–0.7 Bq (20–40 dpm) of alpha (see Fig. 4).

7.1.5 Mixing, Pump, and Well Cells

High levels of direct [1.5-40 mGy (150-4,000 mrad/h)] and removable [0.05-0.35 mGy (5-35 mrad) beta-gamma and less than 1.7 Bq/100 cm^2 of alpha] contamination were found in these cells, as shown in Figs. 5, 6, and 7.

7.1.6 Pump Room

The interior surfaces of the pump room are contaminated with fixed and removable activity at 0.2-80 mGy/h (20-8000 mrad/h) and 5-150 μGy (0.5-15 mrad/h), respectively as shown in Fig. 8.

7.1.7 Engine Pad

Elevated absorbed dose rates of 0.2-3 mGy/h (20-300 mrad/h) were detected 10 cm above the engine pad. The pad was found to be contaminated with 5-10 μGy/h (0.5-1 mrad/h) of removable beta-gamma activity and 0.5 Bq (30 dpm) of removable alpha activity per 100 cm^2 using wet towel smear techniques. These results are shown in Fig. 9.

7.1.8 Valve Pit

The direct radiation above the sheet metal covering the concrete blocks of the valve pit was 50 μGy/h (5 mrad/h). The interior of the pit is potentially contaminated with fixed and removable activity.

7.1.9 Pipe System

The interior of the waste process lines is potentially contaminated. Some of these pipelines are marked on Fig. 3.

7.2 IDENTIFICATION OF RELATIVELY UNCONTAMINATED AREAS

The following areas are considered to be relatively uncontaminated, with no serious radiological impacts expected.

7.2.1 General Vicinity of OHF

Slightly elevated dose rates were detected over the entire general area. However, soil analyses show that most of the surface and subsurface soil samples from the the vicinity of OHF were uncontaminated. Low levels of contamination were found in two soil samples, 3-4 and 10-1.

7.2.2 Pond Perimeter

Sample 3-4 was collected from the soil layer, 1.2-1.8 m belowgrade, which corresponds to the depth of the water-sediment layer in the pond. The low level of contamination in sample 3-4 could suggest a leak from the pond. No serious contamination was identified in the surface and subsurface soil around the pond perimeter.

7.2.3 Storage Bins

Four storage bins were used to store uncontaminated cement, fly ash, gravel, and other additive material. The structures of these bins are deteriorating and may cause safety concerns.

7.2.4 Water Tank

A 97,000-L water tank, T-5, is located at the east side of the OHF site. The tank is still full of uncontaminated water and has been scheduled for removal.

7.2.5 Butler Building (Building 7853)

Building 7853, known as the Butler Building, was used as a change room. It is still in a sound condition and is currently used as a storage facility. Plans are to continue to use it for this purpose.

8. CONCLUSIONS

The interior areas of the OHF are highly contaminated (summarized in Table 12). Much of the contamination appears to be transferable, so an initial clean up effort might reduce radiation levels significantly. However, current radiation and contamination levels are so high that estimates of the reduction are impossible, because isolated areas of fixed contamination are "hidden" by the radiation background.

The waste tanks, waste pond, and waste pit are radiation and contamination sources that contain approximately 200 TBq (5 kCi), 15 TBq (400 Ci), and 20 GBq (0.5 Ci) of radioactivity, respectively (Table 11). The radioactivity in the waste pit may be significantly higher since the solidified part of the pit was not included in the calculations.

Because the sediment in the pond is contaminated not only with radionuclides, but also with low levels of PCBs and heavy-metals, special consideration should be given to disposal methods. An additional permit may possibly be needed for the handling and disposal of PCB and heavy-metal-contaminated low-level waste. Concentrations of PCBs and heavy metals in the pond sediment were very low, and the total volume was limited (less than 4×10^4 L); however the disposal of any detectable amount of PCBs in the environment is not permitted by EPA regulation.[15]

The underground waste-transfer lines connecting the contaminated areas, discussed in Sect. 2.10, are likely still in place. The interior of these waste-lines is potentially still contaminated.

Contamination at the OHF appears to be confined to localized areas. No apparent leaks were detected in the vicinity of the potential radiation hazards discussed in Sect. 7.1.

Major radionuclides are ^{137}Cs, ^{90}Sr, and ^{60}Co; low but significant levels of transuranic alpha-emitting radionuclides are also present.

Regardless of the method of decommissioning, both the Radiation and Safety Surveys Department and Department of Environmental Management should be contacted to ensure that radiation exposure and environmental pollution are limited by the intent and spirit of the ALARA (As Low As Reasonably Achievable) principle.

9. REFERENCES

1. H. O. Weeren, Shale Fracturing Injections at Oak Ridge National Laboratory – 1975 Series, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL/TM-5545, 1976.

2. H. O. Weeren, Shale Fracturing Injections at Oak Ridge National Laboratory – 1977-1979 Series, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL/TM-7421, 1980.

3. H. O. Weeren, "Environmental Effects of Disposal of Intermediate-Level Wastes by Shale Fracturing," Proceedings of the American Institute of Chemical Engineers, New York, Nov. 1978.

4. F. T. Binford, ORNL Intermediate-Level Waste System Modifications, Preliminary Safety Analysis Report, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL/CF-75/11-2, 1975.

5. W. de Laguana, H. O. Weeren, F. T. Binford, E. J. Witkowski, and E. G. Struness, Safety Analysis of Waste Disposal by Hydraulic Fracturing at Oak Ridge, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL-4665, 1971.

6. W. A. Burkhardt, "Transport of Radionuclides from a Contaminated Pond by Emerging Aquatic Insects," Master of Science Thesis, Virginia Polytechnic Institute and State University, March 1984.

7. S. F. Huang et al., The Environmental Radiological Characterization of the Homogeneous Reactor Experiment No. 2, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL/CF-84/201, 1984.

8. E. D. Gupton, Health Physics Instrument Manual, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL/332, 1961.

9. J. S. Eldridge and S. F. Huang, Radioactivity Determinations in Decontamination and Decommissioning, Analytical Chemistry Division Annual Report, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL/CF-83/91, 1983.

10. T. W. Oakes et al., Methods and Procedures Utilized in Environmental Management Activities at Oak Ridge National Laboratory, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL/TM-7212, 1981.

11. ORNL Health Physics Procedure Manual, Oak Ridge National Laboratory, Oak Ridge, TN, Procedure 2.7, Table 2, 1970-1984.

12. J. A. Auxier and T. W. Oakes, Industrial Safety and Applied Health Physics Division Annual Report for 1981, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL-5859, 1981.

13. H. O. Weeren, Hydrofracture Injections at Oak Ridge National Laboratory, 1982-1984 Series, Oak Ridge National Laboratory, Oak Ridge, TN, ORNL/NFW-84/43, 1984.

14. R. H. Perry and C. H. Chilton, Chemical Engineer's Handbook, 5th edition, McGraw-Hill Book Company, New York, 1973.

15. Polychlorinated Biphenyls (PCBs) - Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions, 40 CFR 425.10, Federal Register, Government Printing Office, Washington, D.C., 1980.

ORNL/CF-84/202
Internal Use Only

INTERNAL DISTRIBUTION

1. J. F. Alexander
2. W. A. Alexander
3. H. M. Butler
4. H. M. Braunstein
5. J. H. Coobs
6. N. W. Durfee
7. J. S. Eldridge
8. P. K. Gulati
9. F. J. Homan
10. J. R. Horton
11-15. S. F. Huang
16. B. A. Kelley
17-26. T. E. Myrick
27. T. W. Oakes
28. W. F. Ohnesorge
29. P. T. Owen
30. R. K. Owenby
31. D. C. Parzyck
32. F. J. Peretz
33. C. R. Guinn
34. W. R. Reed
35. T. G. Scott
36. D. R. Simpson
37. N. A. Teasley
38. V. L. Turner
39. J. B. Watson
40. ICC Publications Office
41-42. Laboratory Records
43. Laboratory Records, RC
44. ORNL Patent Office